MILITARY AND NATIONAL SECURITY IMPLICATIONS OF NANOTECHNOLOGY

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ABSTRACT

All branches of the U.S. military are currently conducting nanotechnology research, including the Defense Advanced Research Projects Agency (DARPA), Office of Naval Research (ONR), Army Research Office (ARO), and Air Force Office of Scientific Research (AFOSR). The United States is currently the leader of the development of nanotechnology-based applications for military and national defense. Advancements in nanotechnology are intended to revolutionize modern warfare with the development of applications such as nano-sensors, artificial intelligence, nanomanufacturing, and nanorobotics. Capabilities of this technology include providing soldiers with stronger and lighter battle suits, using nano-enabled medicines for curing field wounds, and producing silver-packed foods with decreased spoiling rate (Tiwari, A., Military Nanotechnology, 2004). Although the improvements in nanotechnology hold great promise, this technology has the potential to pose some risks. This article addresses a few of the more recent, rapidly evolving, and cutting edge developments for defense purposes. To prevent irreversible damages, regulatory measures must be taken in the advancement of dangerous technological developments implementing nanotechnology. The article introduces recent efforts in awareness of the societal implications of military and national security nanotechnology as well as recommendations for national leaders.

Keywords: Nanotechnology, Implications, modern warfare

INTRODUCTION

Advances in nano-science and nanotechnology promise to have major implications for advances in the scientific field as well as peace for the upcoming decades. This will lead to dramatic changes in the way that material, medicine, surveillance, and sustainable energy technology are understood and created. Significant breakthroughs are expected in human organ engineering, assembly of atoms and molecules, and the emergence of a new era of physics and chemistry. Tomorrow's soldiers will have many challenges such as carrying self-guided missiles, jumping over large obstacles, monitoring vital signs, and working longer periods with sleep deprivation. (Altmann & Gubrud, Anticipating military nanotechnology, 2004). This will be achieved by controlling matter at the nanoscale (1-100nm). A nanometer is one-billionth of a meter. This article considers the social impact of nanotechnology (NT) from the point of view of the possible military applications and their implications for national defense and arms control. This technological evolution may become disruptive; meaning that it will come out of mainstream. Ideas that are coming forth through nanotechnology are becoming very popular and the possibilities will in practice have profound implications for military affairs as well as relations between nations and thinking about war and national security (Altmann J. , Military Uses of Nanotechnology: Perspectives and Concerns, 2004). In this article some of the potential applicability uses of recent nanotechnology driven applications within the military are introduced. This article also discusses how the impact of a rapid technological evolution in the military will have implications on society.

POTENTIAL MILITARY TECHNOLOGIES

Magneto rheological Fluid (MR Fluid)

A magneto-rheological-fluid is a fluid where colloidal ferrofluids experience a body force on the entire material that is proportional to the magnetic field strength (Ashour, Rogers, & Kordonsky, 1996). This allows the status of the fluid to change reversibly from a liquid to solid state. Thus, the fluid becomes intelligently controllable using the magnetic field. MR fluid consists of a basic fluid, ferromagnetic particles, and stabilizing additives (Olabi & Grunwald, 2007). The ferromagnetic particles are typically 20-50μm in diameter whereas in the presence of the magnetic field, the particles align and form linear chains parallel to the field

(Ahmadian & Norris, 2008). Response times that require impressively low voltages are being developed. Recently, (Ahmadian & Norris, 2008) has shown the ability of MR fluids to handle impulse loads and an adaptable fixing for blast resistant and structural membranes. For military applications, the strength of the armor will depend on the composition of the fluid. Researchers propose wiring the armor with tiny circuits. While current is applied through the wires, the armor would stiffen, and while the current is turned off, the armor would revert to its liquid, flexible state. Depending on the type of particles used, a variety of armor technology can be developed to adapt for soldiers in different types of battle conditions. Nanotechnology could increase the agility of soldiers. This could be accomplished by increasing mechanical properties as well as the flexibility for battle suit technology.

Nano Robotics

Nanorobotics is a new emerging field in which machines and robotic components are created at a scale at or close to that of a nanometer. The term has been heavily publicized through science fiction movies, especially the film industry, and has been growing in popularity. In the movie *Spiderman*, Peter Parker and Norman Osborn briefly talk about Norman's research which involves nanotechnology that is later used in the Green Goblin suit. Nanorobotics specifically refers to the nanotechnology engineering discipline or designing and building nano robots that are expected to be used in a military and space applications. The terms nanobots, nanoids, nanites, nanomachines or nanomites have been used to describe these devices but do not accurately represent the discipline. Nanorobotics includes a system at or below the micrometer range and is made of assemblies of nanoscale components with dimensions ranging from 1 to 100nm (Weir, Sierra, & Jones, 2005). Nanorobotics can generally be divided into two fields. The first area deals with the overall design and control of the robots at the nanoscale. Much of the research in this area is theoretical. The second area deals with the manipulation and/or assembly of nanoscale components with macroscale manipulators (Weir, Sierra, & Jones, 2005). Nanomanipulation and nanoassembly may play a critical role in the development and deployment of artificial robots that could be used for combat.

According to Mavroidis et al. (2013), nanorobots should have the following three characteristic abilities at the nano scale and in presence of a large number in a remote environment. First they should have swarm intelligence. Second the ability to self-assemble and replicate at the nanoscale. Third is the ability to have a nano to macro world interface architecture enabling instant access to the nanorobots with control and maintenance. (Mavroidis & Ferreira, 2013) also states that collaborative efforts between a variety of educational backgrounds will need to work together to achieve this common objective. Autonomous nanorobots for the battlefield will be able to move in all media such as water, air, and ground using propulsion principles known for larger systems. These systems include wheels, tracks, rotor blades, wings, and jets (Altmann & Gubrud, Military, arms control, and security aspects of nanotechnology, 2004). These robots will also be designed for specific military tasks such as reconnaissance, communication, target destination, and sensing capabilities. Self-assembling nanorobots could possibly act together in high numbers, blocking windows, putting abrasives into motors and other machines, and other unique tasks.

Artificial Intelligence

Artificial intelligence (AI) is a vast emerging field that can be very thought provoking. AI has been seen recently in a number of movies and television shows that have predicted what the possibility of an advanced intelligence could do to our society. This intellect could possibly outperform human capabilities in practically every field from scientific research to social interactions. Aspirations to surpass human capabilities include tennis, baseball, and other daily tasks demanding motion and common sense reasoning (Kurzweil, 2005). Examples where AI could be seen include chess playing, theorem proving, face and speech recognition, and natural language understanding. AI has been an active and dynamic field of research and development since its establishment in 1956 at the Dartmouth Conference in the United States (Cantu-Ortiz, 2014). In past decades, this has led to the development of smart systems, including phones, laptops, medical instruments, and navigation software.

One problem with AI is that people are coming to a conclusion about its capabilities too soon. Thus, people are becoming afraid of the probability that an artificial intelligent system could possibly expand and turn on the human race. True artificial intelligence is still very far from becoming "alive" due to our current technology.

Nanotechnology might advance AI research and development. In nanotechnology, there is a combination of physics, chemistry and engineering. AI relies most heavily on biological influence as seen genetic algorithm mutations, rather than chemistry or engineering. Bringing together nanosciences and AI can boost a whole new generation of information and communication technologies that will impact our society. This could be accomplished by successful convergences between technology and biology (Sacha & P., 2013). Computational power could be exponentially increased in current successful AI based military decision behavior models as seen in the following examples.

Expert Systems

Artificial intelligence is currently being used and evolving in expert systems (ES). An ES is an "intelligent computer program that uses knowledge and interference procedures to solve problems that are difficult enough to require significant human expertize to their solution" (Mellit & Kalogirou, 2008). Results early on in its development have shown that this technology can play a significant impact in military applications. Weapon systems, surveillance, and complex information have created numerous complications for military personnel. AI and ES can aid commanders in making decisions faster than before in spite of limitations on manpower and training. The field of expert systems in the military is still a long way from solving the most persistent problems, but early on research demonstrated that this technology could offer great hope and promise (Franklin, Carmody, Keller, Levitt, & Buteau, 1988). Mellit et al. argues that an ES is not a program but a system. This is because the program contains a variety of different components such as a knowledge base, interference mechanisms, and explanation facilities. Therefore they have been built to solve a range of problems that can be beneficial to military applications. This includes the prediction of a given situation, planning which can aid in devising a sequence of actions that will achieve a set goal, and debugging and repair-prescribing remedies for malfunctions.

Genetic Algorithms

Artificial intelligence with genetic algorithms (GA) can tackle complex problems through the process of initialization, selection, crossover, and mutation. A GA repeatedly modifies a population of artificial structures in order to adjust for a specific problem (Prelipcean et al., 2010). In this population, chromosomes evolve over a number of generations through the application of genetic operations. This evolution process of the GA allows for the most elite chromosomes to survive and mate from one generation to the next. Generally, the GA will include three genetic operations of selection, crossover, and mutation. This is currently being applied to solving problems in military vehicle scheduling at logistic distribution centers.

Nanomanufacturing

Nanomanufacturing is the production of materials and components with nanoscale features that can span a wide range of unique capabilities. At the nanoscale, matter is manufactured at lengthscales of 1-100nm with precise size and control. The manufacturing of parts can be done with the "bottom up" from nano sized materials or "top down" process for high precision. Manufacturing at the nanoscale could produce new features, functional capabilities, and multi-functional properties. Nanomanufacturing is distinguished from nanoprocessing, and nanofabrication, whereas nanomanufacturing must address scalability, reliability and cost effectiveness (Cooper & Ralph, 2011). Military applications will need to be very tough and sturdy but at the same time very reliable for use in harsh environments with the extreme temperatures, pressure, humidity, radiation, etc. The use of nano enabled materials and components increase the military's in-mission success. Eventually, these new nanotechnologies will be transferred for commercial and public use. Cooper et al. makes known how nanomanufacuring is a multi-disciplinary effort that involves synthesis, processing and fabrication. There are however a great number of challenges that as well as opportunities in nanomanufacturing R&D such as;

- Predictions from first principles of the progress and kinetics of nanosynthesis and nano-assembly processes.

- Understand and control the nucleation and growth of nanomaterial and nanostructures and asses the effects of catalysts, crystal orientation, chemistry, etc. on growth rates and morphologies.

R&D IN THE USA

The USA is proving to have a lead in military research and development in nanotechnology. Research spans under umbrella of applications related to defense capabilities. NNI has provided funds in which one quarter to one third goes to the department of defense – in 2003, $ 243 million of $774 million. This is far more than any country and the US expenditure would be five times the sum of all the rest of the world (Altmann & Gubrud, Military, arms control, and security aspects of nanotechnology, 2004).

INITIATIVES

The National Nanotechnology Initiative

The National Nanotechnology Initiative (NNI) was unveiled by President Clinton in a speech that he gave on science and technology policy in January of 2000 where he called for an initiative with funding levels around 500 million dollars (Roco & Bainbridge, 2001). The initiative had five elements. The first was to increase support for fundamental research. The second was to pursue a set of grand challenges. The third was to support a series of centers of excellence. The fourth was to increase support for research infrastructure. The fifth is to think about the ethical, economic, legal and social implications and to address the education and training of nanotechnology workforce (Roco & Bainbridge, 2001). NNI brings together the expertise needed to advance the potential of nanotechnology across the nation.

ISN at MIT

The Institute for Soldier Nanotechnologies (ISN) initiated at the Massachusetts Institute of Technology in 2002 (Bennet-Woods, 2008). The mission of ISN is to develop battle-suit technology that will increase soldier survivability, protection, and create new methods of detecting toxic agents, enhancing situational awareness, while decreasing battle suit weight and increasing flexibility.

ISN research is organized into five strategic areas (SRA) designed to address broad strategic challenges facing soldiers. The first is developing lightweight, multifunctional nanostructured materials. Here nanotechnology is being used to develop soldier protective capabilities such as sensing, night vision, communication, and visible management. Second is soldier medicine – prevention, diagnostics, and far-forward care. This SRA will focus on research that would enable devices to aid casualty care for soldiers on the battle field. Devices would be activated by qualified personnel, the soldier, or autonomous. Eventually, these devices will find applications in medical hospitals as well. Third is blast and ballistic threats – materials damage, injury mechanisms, and lightweight protection. This research will focus on the development of materials that will provide for better protection against many forms of mechanical energy in the battle field. New protective material design will decrease the soldier's risk of trauma, casualty, and other related injuries. The fourth SRA is hazardous substances sensing. This research will focus on exploring advanced methods of molecularly complicated hazardous substances that could be dangerous to soldiers. This would include food-borne pathogens, explosives, viruses and bacteria. The fifth and final is nanosystems integration –flexible capabilities in complex environments. This research focuses on the integration of nano-enabled materials and devices into systems that will give the soldier agility to operate in different environments. This will be through capabilities to sense toxic chemicals, pressure, and temperature, and allow groups of soldiers to communicate undetected (Institute for Soldier Nanotechnologies).

SOCIAL IMPLICATIONS

The purpose of country's armed forces is to provide protection from foreign threats and from internal conflict. On the other hand, they may also harm a society by engaging in counter-productive warfare or serving as an economic burden. Expenditures on science and technology to develop weapons and systems sometimes produces side benefits, such as new medicines, technologies, or materials. Being ahead in military technology provides an important advantage in armed conflict. Thus, all potential opponents have a strong motive for military research and development. From the perspective of international security and arms control it appears that in depth studies of the social science of these implications has hardly begun. Warnings about this emerging technology have been sounded against excessive promises made too soon. The public may be too caught up with a "nanohype" (Gubrud & Altmann, 2002). It is essential to address questions of possible dangers arising from military use of nanotechnology and its impacts on national security. Their consequences need to be analyzed.

NT and Preventative Arms Control

Background

The goal of preventive arms control is to limit how the development of future weapons could create horrific situations, as seen in the past world wars. A qualitative method here is to design boundaries which could limit the creation of new military technologies before they are ever deployed or even thought of. One criterion regards arms control and how the development of military and surveillance technologies could go beyond the limits of international law warfare and control agreements. This could include autonomous fighting war machines failing to define combatants of either side and Biological weapons could possibly give terrorist circumvention over existing treaties (Altmann & Gubrud, Military, arms control, and security aspects of nanotechnology, 2004). The second criterion is to prevent destabilization of the military situation which emerging technologies could make response times in battle much faster. Who will strike first? The third criterion, according to Altman & Gubrud, is how to consider unintended hazards to humans, the environment, and society. Nanoscience is paving the way for smaller more efficient systems which could leak into civilian sectors that could bring risks to human health and personal data. Concrete data on how this will affect humans or the environment is still uncertain.

Arms Control Agreements

The development of smaller chemical or biological weapons that may contain less to no metal could potentially violate existing international laws of warfare by becoming virtually undetectable. Smaller weapons could fall into categories that would undermine peace treaties. The manipulation of these weapons by terrorist could give a better opportunity to select specific targets for assassination. Anti-satellite attacks by smaller more autonomous satellites could potentially destabilize the space situation. Therefore a comprehensive ban on space weapons should be established (Altmann & Gubrud, 2002). Autonomous robots with a degree of artificial intelligence will potentially bring great problems. The ability to identify a soldiers current situation such as a plea for surrender, a call for medical attention, or illness is a a very complicated tasks that to an extent requires human intelligence. This could potentially violate humanitarian law.

Stability

New weapons could pressure the military to prevent attacks by pursuing the development of new technologies faster. This could lead to an arms race with other nations trying to attain the same goal. Destabilization may occur through faster action, and more available nano systems. Vehicles will become much lighter and will be used for surveillance. This will significantly reduce time to acquire a targets location. Medical devices implanted in soldiers' bodies will enable the release of drugs that influence mood and response times. For example, an implant that attaches to the brains nervous system could give the possibility to reduce reaction time by processing information much faster than usual (Altmann & Gubrud, Anticipating military nanotechnology, 2004). Artificial intelligence based genetic algorithms could make tactical decisions much faster through computational power by adapting to a situations decision. Nano robots could eavesdrop, manipulate or even destroy targets while at the same time being undetected (Altmann J. , Military Uses of Nanotechnology: Perspectives and Concerns, 2004).

Environment Society & Humans

Human beings have always been exposed to natural reoccurring nanomaterials in nature. These particles may enter the human body through respiration, and ingestion (Bennet-Woods, 2008). Little been known about how manufactured nanoscale materials will have an impact to the environment. Jerome (2005) argues that nanomaterials used for military uniforms could break of and enter the body and environment. New materials could destroy species of plants and animal. Fumes from fuel additives could be inhaled by military personnel. Contaminant due to weapon blasts could lead to diseases such as cancer or leukemia due to absorption through the skin or inhalation.

Improper disposal of batteries using nano particles could also affect a wide variety of species. An increase in nanoparticle release into the environment could be aided by waste streams from military research facilities. Advanced nuclear weapons that are miniaturized may leave large areas of soil contaminated with radioactive materials. There is an increase in toxicity as the particle size decrease which could cause unknown environmental changes. Bennet-woods (2008) argues that there is great uncertainty in which the way nano materials will degrade under natural conditions and interact with local organisms in the environment.

Danger to society could greatly be affected due to self-replicating, mutating, mechanical or biological plagues. In the event that these intelligent nano systems were to be unleashed, they could potentially attack the physical world. There are a number of applications that will be developed with nanotechnology that could potentially crossover from the military to national security that can harm the civilian sector (Bennet-Woods, 2008). There is a heightened awareness that new technologies will allow for a more efficient access to personal privacy and autonomy (Roco & Bainbridge, 2005). Concerns regarding artificial intelligence acquiring a vast amount of personal data, voice recognition, and financial data will also arise. Implantable brain devices, intended for communication, raise concerns for actually observing and manipulating thoughts. Some of the most feared risks due to nanotechnology in the society are the loss of privacy (Flagg, 2005). Nano sensors developed for the battlefield could be used for eavesdropping and tracking of citizens by state agencies. This could lead to improvised warfare or terrorism. Bennet-Woods (2008) argues that there should be an outright ban on nanoenabled tracking and surveillance devices for any purpose.

Nanotechnology in combination with biotechnology and medicine raise concerns regarding human safety. This includes nanoscale drugs that may allow for improvements in terrorism alongside more efficient soldiers for combat. Bioterrorism could greatly be improved through nano-engineered drugs and chemicals (Milleson, 2013). Body implants could be used by soldiers to provide for better fighting efficiency but in the society, the extent in which the availability of body manipulation will have to be debated at large (Altmann J. , Nanotechnology and preventive arms control, 2005). Brain implanted stimulates could become addictive and lead to health defects. The availability of body and brain implants could have negative effects during peace time. Milleson (2013) argues that there is fear that this technology could destabilize the human race, society, and family. Thus, the use in society should be delayed for at least a decade.

CONCLUSIONS

Nanoscience will lead to a revolutionary development of new materials, medicine, surveillance, and sustainable energy. Many applications could arrive in the next decade. The US is currently in the lead in nanoscience research and development. This equates to roughly five times the sum of all the rest of world. It is essential to address the potential risks that cutting edge military applications will have on warfare and civilian sector. There is a potential for mistrust in areas where revolutionary changes are expected. There are many initiatives by federal agencies, industry, and academic institutions pertaining to nanotechnology applications in military and national security. Preventive measures should be coordinated early on among national leaders. Scientists propose for national leaders to follow general guidelines. There shall be no circumvention of existing treaties as well as a ban on space weapons. Autonomous robots should be greatly restricted. Due to rapidly advancing capabilities, a technological arms race should be prevented at all costs. Nanomaterials could greatly harm humans and their environment therefore nations should work together to address safety protocols. The national nanotechnology of different nations should build confidence in addressing the social implications and preventive arms control from this technological revolution.

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